P-223R High Performance Films

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INTRODUCTION

Plastics, in many forms, have become, in the years since World War II, ubiquitous in developed nations the United States, the largest producer and user of polymer products in the world. Synthetic polymers used in many forms, from synthetic fibers to molded products such as bottles and other rigid shaped a mattresses. Oftentimes the same polymer chemistry can produce products with entirely different prope Polyethylene terephthalate (PET) is a good example; it first became well known as a synthetic fiber Dacron® brand), but is now also used extensively as a blow-molding bottle resin (most soft drink bottl PET) and a performance film for photographic and magnetic media.

In this BCC report we study and report on one versatile group of polymer products, high-performanc The noun *film* is defined (*The American Heritage Dictionary*, Second College Edition, 1985) thusly:

> "1. A thin skin or membranous coating. 2. An abnormal thin, opaque coating on the of the eye. 3.a. A thin covering or coating (as a film of dust on the piano), or b. generally flexible transparent sheet, as of plastic used in wrapping or packaging. 4. sheet or strip of flexible cellulose material coated with a photosensitive emulsion, make photographic negatives or transparencies. 5.a. A motion picture. b. Motion p collectively; the cinema. 6. Computer Science. A coating of magnetic alloys on glass manu-facturing storage devices."

The films covered in this report are included in definitions 3.b, 4 and 6, although technology has progre in the years since this edition was published that the "cellulose" in definition 4 is already obsolete, as is for coatings on glass in the computer science definition No. 6.

The *McGraw-Hill Dictionary of Scientific and Technical Terms*, Fourth Edition (1989), defines *film* word's usage in scientific applications:

> "A flat section of thermoplastic resin, a regenerated cellulose derivative, or other n

that is extremely thin in comparison to its length and breadth and has a nominal ma thickness of 0.25 millimeter."

This definition fits the physical characteristics of the films we discuss in this report. The nominal maxi of 0.25 mm is equivalent to 10 mils or 0.01 inch, which is normally considered in the trade to be about t which a "film" of most materials becomes a "sheet."

A word on film thickness units. Both English and metric units are commonly used, the latter aroun addition, in the U.S. film thickness is commonly also expressed in gauge. In film technology, gauge is of film thickness, where one gauge unit equals 0.01 mil or about 0.25 micrometer (micron). Perhaps the remember the relationship between these unit systems is that 100 gauge film is 1 mil or 25 microns thic

STUDY GOALS AND OBJECTIVES

Goals and objectives in this study:

- To give an overview to high performance polymer films and their major end-use application m six major polymer films or film families are discussed and analyzed in detail: polyesters, nylo based performance films, polycarbonates, fluoropolymers and polyimides. In addition, we discus and/or developmental films in a final category which we call "other and developmental" hig films; these are mostly newer, still relatively small volume films which are attempting to find competitive marketplace.

- To discuss, analyze, and forecast markets for performance films by material types, with secti each of our classes of performance films. This includes both the six major resin type developmental, newer film materials for which we were able to estimate markets.

- To analyze and forecast the markets from the viewpoint of eight major applications markets fc films: automotive, electrical/ electronic, magnetic media, packaging, photographic/ reprograph films. In addition, we have estimated the U.S. markets for film in an additional "definable c which encompasses several other markets such as aerospace/aircraft, building/construction stamping films, industrial membranes, office products, pipe thread sealing tape, and signs/display

- For both the materials and applications market analyses, to provide market volumes (in millions base year 1998 and forecasts for 5 years to 2003. For markets by materials we also present estin market values in constant 1998 dollars predicated on average base (bulk, large volume) resin p annual growth rates (AAGRs) are calculated for the 1998-2003 forecast period.

- To discuss current and new developments in resin and film technology, including some basic infc chemistry and manufacture of the plastic resins used to make performance films, film fabricati competitive processes and products, and current research and development.

- To discuss some important factors in the structure of the high-performance plastic films industry, fabricators, converters and distributors, product differentiation and substitution, marketing, pric international aspects of the business.

- To examine environmental and regulatory considerations which affect perfor-mance films, and t products and markets. These include disposal problems, film recycling, biodegradability, and fe regulatory processes.

- To list and briefly profile many of the most important suppliers to the high-performance plastic including suppliers of plastic resins (many of whom also fabricate films but some of whom do no film converters and distributors.

REASONS FOR DOING THE STUDY

High-performance plastic films have become an important niche market in the much larger plastic High-performance plastic films are specialty products that sell at premium prices because they ca commodity films cannot do. Their use is driven by the specific applications for which they are aimed.

Although the volumes of high-performance plastic films used are small when compared to those of co the value of this market is disproportionately high. This occurs because high-performance plastic film specialty items that command higher prices, most of them in excess of $2.00 per pound and many $5.00/lb and even higher. Commodity plastic films, like polyethylene films, are, on the other hand, cheap (really cheap at this time) commodity PE resins that sell for less than 50 cents per pound.

Also, the high-performance plastic films market is a global one, with many foreign-owned firms, suc ICI of Europe and Japan's Kuraray and Toray, active in the U.S. market. Industry leaders have worldv (and some-times manufacturing) capabilities, held either independently or via joint ventures with local c

BCC did this study to provide a comprehensive reference for those interested in and/or involved in thes their use. This is a wide and varied group of companies in many different industries which both make performance plastic films, process technology and equipment designers and marketers, politicians of the general public; all are touched in some way by high-performance plastic films. We have sorte condensed information from a large amount of literature and other reference materials to compile this re

CONTRIBUTION OF THE STUDY AND FOR WHOM

Because of the size and diversity of the materials and products used in high-performance plastic fil should be of interest to a wide group of organizations and individuals, people who are involved in the design, manufacture, sale and use of these films, as well as government officials and the general pub that this report will be of value to technical and business personnel in the following areas, among others

- Marketing and management personnel in companies that produce, market and sell high-performar films.
- Companies involved in the design and construction of process plants that manufacture both the ba and high-performance plastic films themselves.
- Companies which supply, or want to supply, equipment and services to high-performance plastic companies.
- Financial institutions which supply money for such facilities and systems, including banks, merch venture capitalists and others.
- Personnel in end-user companies in a wide range of industries, ranging from aerospace to photo fi packaging.
- Personnel in government at many levels, ranging from the federal to state and local authorities, m

are involved in trying to ensure public health and safety.

SCOPE AND FORMAT

This BCC study covers in depth many of the most important economic, technological, political, environmental considerations in U.S. markets for high-performance plastic films. These products a several different types of materials and in different designs.

Our study includes key technologies (and new technologies), the markets, and key player companies v the U.S. performance films market. This is a study of activities and markets in the United States; howe the global nature of this market and its materials and products, we touch upon some international aspect

BCC's scope includes those plastic films that we (and the industry) consider to be "high-performance. thermoplastic materials with the possible exception of polyimides, which are usually technically co "pseudo-thermoplastic."

High-performance films may be defined in any of several ways: by volume, price, performance, en resin types or a combination of two or more of these characteristics. For this study, high-perform defined as those which fill a unique or special place in the marketplace and which meet a market ne easily be filled by some other film or product. A performance film is thus identified by its prope performance. In general, this means thin gauge, mostly extruded or solution cast polymer sheets, most the following criteria: list price close to or greater than $2.00/lb; continuous use temperatures above 10 uses other than packaging; and thicknesses at or below 10 mils (30 mils or less for polycarbonate film).

Thus, in general, to qualify as a performance film, one must meet certain minimum criteria, among then

- It will be expensive, with list prices greater than $1.00 per pound and usually closer to $2.00/lb noted above, some films cost $5.00 per pound or considerably higher. At this time, many base largest volume performance film, PET, are selling for more like a dollar a pound in a time of ov low markets in Asia; this will probably change in the future as Asia recovers and supply and more into balance.

- It will be thin gauge, with thicknesses usually 10 mils or less for most resins. In certain cases, n polycarbonate films, thicker films are formed, up to 30 mils in thickness.

- It has special performance characteristics, such as the ability to be used at high temperatures ab point of water, high strength and/or wear resistance, etc.

- It finds significant applications other than in packaging. This is a key criterion, for packagin major end use for many commodity resins, especially polyolefins such as polyethylenes. Howe remains a major application for some performance films, both for polyesters and for films wit properties such as EVOH and nylon. In this case, it is excellent performance which allows muc new packaging -- primarily for foods -- to allow extended shelf life. Thus, this type of packagin the "high-performance" nature of these films.

- The film will be made from a specialty thermoplastic polymer, formed into sheets by a varie processes. Most film is fabricated by extrusion casting (flat film or die extrusion), but some a Polytetra-fluoroethylene (PTFE, DuPont's first Teflon® brand product) cannot be melt-processe like conventional thermoplastics and requires special techniques such as "skiving" (peeling thin

from a solid slab), paste extrusion, or dispersion casting. New fabrication techniques include c increasingly popular multilayer structures which combine the advantages of several resins.

- The performance film will usually have good high temperature resistance and can be used temperatures above 100°C.

High-performance films are generally fabricated (or converted) in relatively small volumes, and often a on the basis of value to customers than on a manufacturing cost basis. Decisions regarding inclusion or particular material or product are of course somewhat arbitrary, especially when they are based on one's term such as "performance." BCC's definition of what constitutes performance excludes commodity fi polyolefins), and includes the most important current and developing specialty plastic films.

The focus of this study is on six broad classes of films which cover a variety of resins, plus one catc developmental class" of smaller volume, often still experimen-tal films. These are:

- Polyester films, primarily those fabricated from polyethylene terephthalate or PET; we use PET i with polyester throughout this report. These are the largest volume films, used primarily for reprographic films and magnetic media such as tapes and disks. We include PET films as perf some in the trade consider PET a commodity thermoplastic, and in many of its uses, such as i soft drink bottles, it has become a commodity. We include them because, despite usage approa pounds per year, most applications are not in packaging, and most are high technology us magnetic tapes and other media.

- Nylon films, primarily cast and oriented nylon 6 and 6/6. Nylon films find primary appli packaging for their strength and good barrier properties.

- Polyolefin-based films, five of which are used in significant volume: ethylene-vinyl alcohol (EV polymethylpentene (PMP), polyvinylidene chloride (PVdC), and polyvinyl alcohol (PVOH) film are growing rapidly in packaging applications, especially in barrier films for food packaging. also find major application in food packaging. PMP films find use primarily in packaging ar applications. PVdC is the older food and pharmaceutical barrier film, now losing market share to fluoropolymer PCTFE. PVOH is the best oxygen barrier film known, but because it is wate limited use, and much of this use takes advantage of its solubility.

- Polycarbonate films, which find primary use in the graphic arts; for example, in instrument pa automotive end uses, signs and nameplates.

- Fluoropolymer films, made from PTFE and seven other fluoropolymers: chlorotrifluoroethyl fluoride copolymer (PTCFE or CTFE-VDF), ethylene-chlorotrifluoroethylene copolymer (ECT tetrafluoroethylene copolymer (ETFE), fluorinated ethylene-propylene copolymer (FEP), tetrafluoroethylene copolymer (PFA), polyvinylidene fluoride (PVDF), and polyvinyl fluorid resins -- PTFE (the largest), FEP, PTCFE, PVDF and PVF -- dominate the market, finding use applications.

- Polyimide films, high priced films used primarily in small volumes in electrical/electronic appli in printed circuits, wire and cable wrapping, and motor/generator insulation. Polyimide films i types of polyimides made from monomers such as pyromellitic dianhydride and biphenyl dianhydride.

- Finally, what we call "other and developmental" films, a catchall classification for a number (which are trying to find their place in the market. For several of these films which have some c can estimate their markets; these include liquid crystal polymers (LCPs), polyethylene naph- polyketones (primarily polyetherether ketones or PEEK films), polysulfones (PSO, PE polyetherimide (PEI), and polyphenylene sulfide (PPS). In addition, there are a few high perform are so new, or whose uses are so small, that we cannot estimate their markets at this time; polyarylates, thermoplastic elastomers (TPEs), poly-trimethylene terephthalate (PTT), ber (BCB), and cycloolefin copolymer (COC) films.

We consider all these types of plastic films to be "high-performance" films. Some others in th differentiate between the larger volume films, like polyester, nylon, polyolefin-based and polycarbonat more exotic fluoropolymers, polyimides and developmental films. They call the whole family "special the higher volume group called "engineering" films and the others true high-performance films. Since meet out criteria for high performance, we use this term to describe them all.

This report in segmented into sections, of which this Introduction is the first.

The Summary encapsulates our findings and conclusions, and includes the sum-mary market table. where the busy executive can find the major structure and findings of the study in summary format.

Next is a section on background and overview of the high-performance plastic films industry. We intr resins and the films themselves, suppliers and endusers, pricing, and a brief overview of the major mark

Next come two sections, the heart of the report, which analyze and forecast U.S. markets for high-perfc films. The first market analysis section is devoted to markets segmented by the various types of films, major applications. In each section we start each part with our market table or tables, then discuss markets and factors that led to the construction of our market analysis.

The Technology section is next, with subsections devoted to plastic resin and film manufacture, film f some new developments.

Next is a section devoted to the structure of the high-performance plastic films industry and some com within it that help explain its dynamics. We look at film producers, both integrated and nonintegrated, distributors, product differentiation, marketing, pricing and international aspects. All of these are factor dynamics of the industry.

This is followed by a discussion of environmental and regulatory factors which affect the high-perfo films industry. These include some ongoing environmental issues such as film disposal and recycli government regulations over the industry.

Our section devoted to high-performance plastic films supplier firms is next, with brief profiles of ma important players in this industry. This includes companies that make only basic film resins, those that (some firms do both), and those that distribute and market them.

Finally, we end the report with a glossary of some important terms, abbreviations, acronyms, etc. us performance plastic films industry and related technologies.

Some topics and materials discussed in this report, especially in the technology section, are not include forecast tables. These include the newest and least developed films noted above under "other and c

films.

For consistency in style and format, trade names are indicated by capitalization and the ® symbol report; generic names are in lowercase script. Hence, we speak of DuPont's Teflon® brand of fluorop polytetrafluoroethylene as a generic polymer. In many cases, particular film resins are called by u acronyms derived from their long chemical names, such as PTFE for polytetrafluoroethylene polymethylpentene.

We estimate demand data for our base year of 1998, and forecast for 5 years to 2003. Markets are projected in both volumes in pounds and in constant 1998 dollars. The 5-year growth rates are al (signified as average annual growth rates, or AAGRs). Most final market figures are rounded to the pounds or dollars.

However, because of the low market volumes for some classes such as fluoropolymer and polyimide fil their volumes in 0.1 million (100,000-pound) segments; this more detailed presentation does not precision in the numbers but is used simply to give a better idea of the magnitude of these smaller mark this rounding, especially in smaller markets, AAGRs may not exactly agree with market numbers.

METHODOLOGY AND INFORMATION SOURCES

Extensive searches were made of the literature and the Internet, including many of the leading trade pu well as technical compendia, government publications, and information from trade and other asso product and market information was obtained from the principals involved in the industry. Other so directories, articles and Internet sites.

- P-230 The Changing Flexible Packaging Industry
- P-229 Beverage Packaging Materials/Products: Winners and Losers
- P-233 Resins in Electronic Equipment Enclosures
- P-146R Polymeric Materials and Flame Retardants for Wire and Cable
- P-231 Advanced Inorganic Fillers for Plastics
- P-123N Plastics/Elastomers Under the Hood: A Robust Market
- P-164 Engineering Resins: High Performance, Traditional, and Alloys/Blends - A Realistic Appra Competitive Environment
- DPF98 1998 BCC Plastics Factbook

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